NAVAL HEALTH RESEARCH CENTER

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SUMMARY

Introduction

Studies of preventable deaths in civilian medical facilities indicate that some deaths may be preventable through changes in medical practices. While the battlefield environment presents unique challenges to the treatment of severe traumas, it is possible that deployment of new medical equipment and/or training could yield reductions in combat deaths.

Objective

The objective of the present effort was to examine clinical records of combat deaths from a previous military engagement to determine if such lives might now be salvageable if the same traumas were sustained today. In those instances where a combat trauma is now believed to be salvageable, the technologies/training that might yield the lifesaving differences were examined.

Methods

Clinical records were obtained for 210 combat trauma cases that ended in death subsequent to reaching a medical treatment facility. Four surgeons were recruited to review these records and assess the preventability of death if the traumas were sustained today, and to provide judgments as to now-available medical technologies and/or training that might make a lifesaving difference.

Results

In 8% of the cases, the four surgeons independently agreed that the deaths would be possibly preventable if the same traumas were incurred today; in an additional 17% of the cases, three of the four surgeons judged the deaths to be possibly preventable today. The fatal wounds most often viewed as salvageable today were hemorrhage, severe burns, pulmonary edema, and sepsis. The medical technologies most often mentioned to have a potentially lifesaving effect were ventilators/respirators, CT scanners, ultrasound, and antibiotics. The types of training most often mentioned to have a potentially lifesaving impact were damage control, ventilator management, liver packing, respiratory distress management, and burn management.

Conclusions

The judgments of the surgeons reviewing the records of this study indicate that a reduction in the incidence of combat deaths through improved medical technologies and training is possible.

An Assessment of the Potential for Reducing Future Combat Deaths Through Medical Technologies and Training

INTRODUCTION

In the aftermath of combat operations in which casualties are sustained, questions often arise as to whether some deaths might have been prevented had certain medical technologies been deployed or specific medical training been implemented. Even where the deployment of certain medical equipment or training could conceivably make a lifesaving difference, it is important to note that immediate access to the wounded on the battlefield is often constrained by the operational environment. Examples of such constraints would include ongoing hostilities that prevent medical personnel from reaching the wounded individual and/or the absence of knowledge that an individual has even been wounded. Also important to any discussion of potentially "preventable" combat deaths is the terminology used to refer to different casualties. A serviceman who succumbs to his injuries before reaching a medical treatment facility is typically termed a KIA (killed in action);[1] those individuals who expire after reaching a treatment facility are most often categorized as a DOW (died of wounds) or as a DIH (died in hospital).

While combat deaths might be reduced through changes in battle tactics, advances in body armor, or through other nonmedical interventions, the focus of the present investigation is on the care received after the wounded soldier reaches a treatment facility. The notion that some hospital deaths may be preventable is not a new one.[2] A 1985 review by Cales and Trunkey listed no fewer than 29 preventable trauma death studies.[3] One study, conducted at hospitals affiliated with the New York Medical College, classified 11.9% of the trauma deaths as preventable.[4] A study of fatal traumas in Dublin categorized 9 of 28 deaths (32%) after hospital admission as potentially preventable.[5] Another study examining trauma deaths in Denver judged 3% of the deaths to be potentially preventable and another 2% to be frankly preventable.[6]

The aforementioned trauma studies have used panels of surgeons to evaluate whether deaths were preventable. These subjective ratings are typically based on review of pre-death clinical records and/or autopsy records. Approaches vary in these studies with regard to whether a "preventable" death requires unanimous agreement of the experts or whether a simple majority of the panel is sufficient. It is also noted that inter-rater reliability of preventable death judgments has, in the past, not been found to be high.[7]

That some trauma deaths within state-of-the-art hospitals are being deemed "preventable" leaves open the possibility that some trauma deaths treated in less sophisticated medical facilities in combat zones might likewise be preventable. The present study examines clinical records of combat trauma cases that ended in death after reaching a medical treatment facility. The objective of this investigation is to posit medical technologies and/or training that might reduce battlefield deaths in future combat deployments by examining the potential preventability of combat deaths among individuals who died of their traumas after arriving at treatment facilities.

METHOD

Using an inpatient database maintained at the Naval Health Research Center,[8] 960 hospital admissions were identified of U.S. Marines wounded in combat in Vietnam between 1965 and 1969 and who subsequently died in the hospital. A random sample of 300 of these records was requested from the National Personnel Records Center (NPRC) in St. Louis, Missouri. Because some clinical accounts are either never fully documented or are subsequently lost in the transfer of records from a combat zone, a total of 210 records of DIH combat traumas were available for this analysis. No systematic differences were found between the diagnoses in the inpatient database of the records that were available and those that were unavailable. Moreover, post hoc sample size analysis[9] indicated the sample to be representative of the overall population of DIHs at a 95% confidence level with a .06 margin of error.

The clinical records obtained from NPRC varied as to the degree of documentation contained therein. Some records had extensive documentation of nurse's notes, doctor's notes, treatments provided, and autopsy documentation. Other records, especially those of casualties who expired shortly after arriving at a treatment facility, were considerably more abbreviated. Before the records were given to the surgeons for review, all information identifying the patient, next of kin, and medical personnel who treated the individual were redacted. Four surgeons with extensive trauma experience were recruited to review the clinical records. The surgeons did not know who their fellow reviewers were, nor were there any communications among the surgeons. A separate electronic questionnaire for each of the 210 trauma cases was provided to each surgeon. The questionnaire is displayed as Figure 1.

Figure 1. Reducing Combat Deaths Questionnaire

RECORD NO. 001

1. Do you think the death was preventable given the state of medicine 30 yrs ago when the trauma was sustained?
definitely preventable, ❑
possibly preventable, ❑
not salvageable, ❑
can't determine from the available information ❑

1b. What specific factors from record contribute to this opinion? No answer needed for "can't determine."

1c. If life was salvageable, what do you think would have been likely ensuing 'quality of life'?

2. If this life was not salvageable when this trauma was originally sustained, do you believe this death would be preventable if the trauma were sustained today?
definitely preventable, ❑
possibly preventable, ❑
not salvageable, ❑
can't determine from the available information ❑

2b. What factors in the record lead you to that opinion?

2c. If the life is now salvageable, what would the likely 'quality of life' be for that individual?

3. Do you believe there is specific medical training that might be provided to military physicians today that would make the difference between this patient living and dying?

Yes ❑ No ❑

3b. If yes, what specific training would make that difference?
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4. Might the deployment of specific newly-available medical technologies/equipment to combat zone treatment facilities make the difference between this patient living and dying?

Yes ❑ No ❑

4b. If yes, what specific technologies would make that difference?
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5. Might the actions of a non-physician first responder (hospital corpsman, medic) make a difference in whether this life could have been saved?

Yes ❑ No ❑

5b. If yes, what training/equipment would the first responder need in order to make a difference in the saving of this life?

RESULTS

Types of Traumas, Wounding Agents, and Surrounding Circumstances

The general causes of death, as extracted from the clinical records, are shown in Table I. As can be seen, the most commonly recorded causes for these combat deaths were intracranial injuries and hemorrhage/coagulopathy. The wounding agents, also extracted from the clinical records, are displayed in Table II. Three-fourths of the trauma admissions were recorded as resulting from gunshot wounds and explosive devices. Figure 2 is a presentation of the lengths of time between hospital admission and death among the combat trauma cases; time of admission was known for 186 of the 210 cases. As can be seen in this figure, almost 19% of the deaths occurred within two hours of admission, and 59% of the deaths occurred within the first 12 hours.

"Time of injury" was recorded on 109 records. In 55% of these cases, the injury-to-admission time was 1 hour or less; in 23% of these traumas, admission was between 1 and 2 hours of injury; and in another 10% of these cases, admission was within 3 hours. Most records gave no

indication as to what, if any, treatment was provided at the corpsman or battalion aid station level before arrival at the hospital.

Two hundred and four of the trauma cases expired at fixed or shipboard treatment facilities in the combat zone; three cases expired at a facility in Japan; and three cases were transferred to the continental United States before the death occurred. One hundred eighty-nine of the 210 traumas expired at the initial treatment facility where taken after the injury was sustained; 19 cases were transferred to a second facility before the death occurred; and there was a single case each where there were transfers to a third and fourth facility.

Table I. Causes of Death Among Combat Trauma Cases Dying in Hospitals

Cause of Death	Number	Percent
General intracranial injury	68	32.4%
Hemorrhage and coagulopathy	39	18.6%
Cerebral hemorrhage, edema, or hematoma	24	11.4%
Multiple organ complications	13	6.2%
Brainstem injury	12	5.7%
Severe burns	11	5.2%
Sepsis	8	3.8%
Pulmonary edema	6	2.9%
Acute respiratory distress syndrome (ARDS)	2	1.0%
Atelectasis	2	1.0%
Flail chest	2	1.0%
Hemopneumothorax	2	1.0%
Hemothorax	2	1.0%
Laceration to major blood vessels	2	1.0%
Spinal cord injury	2	1.0%
Bronchopneumonia	1	0.5%
Cardiovascular collapse	1	0.5%
Cerebral anoxia	1	0.5%
Encephalopathy	1	0.5%
Fat embolus syndrome	1	0.5%
Hepatic trauma	1	0.5%
Lung contusion	1	0.5%
Lung tissue destruction	1	0.5%
Iatrogenic Event involving Anesthesia	1	0.5%
Meningitis	1	0.5%
Pneumothorax	1	0.5%
Pulmonary hematoma	1	0.5%
Pulmonary hemorrhage	1	0.5%
Pulmonary insufficiency	1	0.5%
Pulmonary obstruction	1	0.5%

Table II. Wounding Agents Among Combat Trauma Patients Dying in Medical Treatment Facilities

Weapon	Count	Percent
Gunshot	107	51.0%
Explosive device	58	27.6%
Booby trap	10	4.8%
Mine	10	4.8%
Mortar	9	4.3%
Shrapnel	3	1.4%
Artillery	2	1.0%
Gasoline fire	2	1.0%
Grenade	2	1.0%
Mine/fire	2	1.0%
Downed helicopter	2	1.0%
Blast	1	0.5%
Booby trap/fire	1	0.5%
Howitzer	1	0.5%

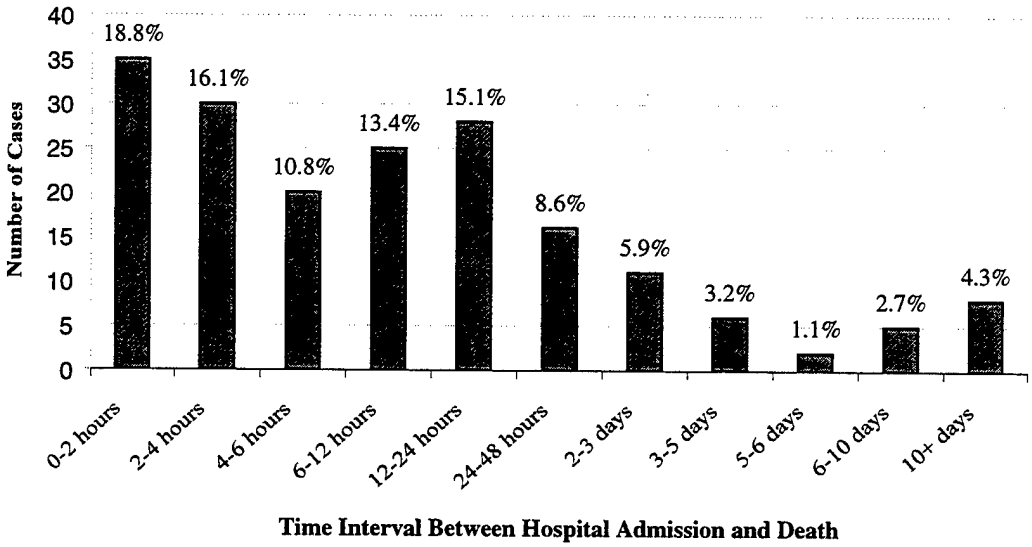

Figure 2. Time Interval Between Hospital Admission and Death Among Combat Trauma Patients Dying in Medical Treatment Facilities.

Preventability Analyses

The percentage of trauma deaths judged "definitely preventable" today by the four individual surgeons ranged from 1.0% to 11.0%, with a mean of 5.4%. The percent of DIHs viewed as "possibly preventable" today varied from 26.2% to 41.9% and averaged 34.9%. Table III is a tabular display of the percentages corresponding to the preventable/unsalvageable responses of the four surgeons to the 210 trauma cases reviewed.

Table III. Responses of Trauma Surgeons Reviewing Clinical Records of Combat Traumas as to Whether Such Deaths Would Be Preventable if Injuries Were Sustained Today

	Surgeon 1	Surgeon 2	Surgeon 3	Surgeon 4	Average
Def. Preventable	6.7%	2.9%	11.0%	1.0%	**5.4%**
Poss. Preventable	39.5%	31.9%	26.2%	41.9%	**34.9%**
Not Salvageable	51.9%	63.8%	55.7%	49.0%	**55.1%**
Can't Determine	1.9%	1.4%	7.1%	8.1%	**4.6%**

There was a fair amount of agreement among the trauma surgeons participating in this study as to whether specific trauma deaths, if seen today, would be preventable. Table IV indicates that at least 3 of the 4 surgeons were in agreement regarding the preventability of the death in 159 of the 210 trauma cases. Additionally, there were another 16 cases where at least three surgeons indicated that the deaths were definitely or possibly preventable today (for example, two said "definitely preventable" and one said "possibly preventable"). A traditional measure of inter-rater reliability, the kappa statistic,[10] yielded a value of 0.32 when the level of agreement among the surgeons was analyzed. Kappa statistics above 0.60 signify substantial to almost perfect agreement; those between 0.41 and 0.60 indicate moderate agreement; those between 0.21 and 0.40 reflect fair agreement; and those below 0.20 represent negligible agreement beyond chance.[7]

Table IV. Number of Trauma Cases in Which at Least Three of the Four Surgeons Agreed as to Salvageablity if the Trauma Were Sustained Today

	Definitely Preventable	Possibly Preventable	Unsalvageable	Can't Determine	Total
All four surgeons	0	17	59	0	76
Three surgeons	1	36	46	0	83
Total	1	53	105	0	159

Table IV may be contrasted with Table V, which indicates that there was not unanimous agreement that any of the trauma deaths were, at the time that they were sustained, "definitely preventable" or even "possibly preventable." Furthermore, there was only one trauma in which three surgeons judged the death to be definitely preventable at the time it occurred and 11 traumas in which three surgeons judged the death to be possibly preventable at time of sustainment.

Table V. Number of Traumas With Unanimity/Near-Unanimity of Agreement as to Salvageability Given Technologies Available at Time the Injury Was Sustained

	Definitely Preventable	Possibly Preventable	Unsalvageable	Can't Determine	Total
All four surgeons	0	0	105	0	105
Three surgeons	1	11	49	3	64
Total	1	11	154	3	169

Unsalvageable Then but Possibly Preventable Today

There were 26 trauma cases where three or more surgeons thought the life was unsalvageable 30 years ago but where the death was judged by at least three surgeons to be definitely/possibly preventable if the same trauma were sustained today. Examination of these cases may provide some insights into the types of traumas that may be most likely to benefit from the deployment of new medical technologies or training regimens. Table VI is a display of the causes of death among those traumas deemed unsalvageable when they occurred but possibly salvageable today.

Table VI. Traumas Judged Originally Unsalvageable but Salvageable Today

Cause of Death	Number	Percent
Hemorrhage and coagulopathy	8	30.8%
Severe burns	3	11.5%
Atelectasis	2	7.7%
Pulmonary edema	2	7.7%
Sepsis	2	7.7%
ARDS	1	3.8%
Brainstem injury	1	3.8%
Bronchopneumonia	1	3.8%
Cerebral hemorrhage, edema, or hematoma	1	3.8%
Fat embolus syndrome	1	3.8%
Hemopneumothorax	1	3.8%
Hepatic trauma	1	3.8%
Laceration to major blood vessels	1	3.8%
Lung contusion	1	3.8%

Table VII presents the types of technology/equipment that the surgeons indicated might make a lifesaving difference among the 26 trauma cases that were viewed to be salvageable today but not when they occurred. It can be seen from this table that the equipment most mentioned as having a potential lifesaving effect were modern ventilators/respirators and computed tomography (CT) scanners.

Table VIII similarly presents the training that the surgeons judged would be most likely to have a potential lifesaving impact, based on the 26 combat traumas that were judged to be salvageable today but not when they occurred 30 years ago. Leading this list were training in damage control, ventilator management, liver packing, and respiratory distress management.

In 10 of the 26 trauma cases judged "now salvageable," three or more surgeons thought the ensuing quality of life would be good or normal; in 4 of the cases, the quality of life was expected to be poor; and in the remaining 12 cases there was no general agreement among the surgeons of the ensuing quality of life.

Table VII. Medical Technologies Indicated to Have Potential Lifesaving Effect

Technology/Equipment	# of Mentions
Modern ventilators/respirators	23
CT Scanner	10
Modern antibiotics	6
Ultrasound/Doppler ultrasound	5
Portable ICU	4
Angiography	3
Dialysis equipment	3
Hemoglobin solutions	3
Portable/Flexible bronchoscope	2
Interventional radiology	2
Swan Ganz catheter	2
Low molecular weight heparin	1
Cardiac echo	1
Heart bypass equipment	1
Bovie electrocautery	1
Argon Beam laser	1
Oxygen saturation monitoring	1
Hemodynamic monitors	1

Table VIII. Medical Training Cited as Having a Potential Lifesaving Effect.

Recommended Area of Training	# of Mentions	Recommended Area of Training	# of Mentions
Damage control surgery	10	Management of pancreatic injuries	1
Ventilator management	9	Advanced trauma life support	1
Liver packing/damage control	8	Hemodynamic monitoring	1
Respiratory distress management	8	Deep vein thrombosis prophylaxis	1
Burn care/modern burn management	4	Postop ICU care	1
Fluid Resuscitation	2	Thoracic surgical training	1
Ultrasound	2	Use of pulmonary artery catheters	1
Invasive interventional radiology	2	Use of draining in pelvic/rectal trauma	1
Oxygen saturation monitoring	2	Pulmonary CT scanning	1
Angiography	1	Bronchoscopy	1
Intracranial Pressure control	1	Hepatic exposure surgical techniques	1
Abdominal compartment syndrome	1		

Types of Deaths with Most and Least Preventability Potential

As was indicated in Table IV, there were 17 trauma cases in which all four surgeons independently indicated that they believed that, were the traumas sustained today, the deaths would be "possibly preventable" and another 36 trauma cases in which 3 of the 4 surgeons independently judged the death to be "possibly preventable" if sustained today. The causes of death in the 17 traumas where there was unanimity of agreement were sepsis in 5 cases, hemorrhage/coagulopathy in 4 cases, pulmonary edema in 2 cases, and cerebral edema, respiratory distress, hemopneumothorax, atelectasis, lung tissue destruction, and fat embolus syndrome in 1 case each. The causes of death among the 36 traumas where there was near-unanimity that the deaths would be "possibly preventable" were hemorrhage/coagulopathy in 15 cases, severe burns in 4 cases, multiple organ trauma in 3 cases, general intracranial injury and intracerebral hemorrhage in 2 cases each, and brainstem injury, encephalopathy, pulmonary insufficiency, pulmonary obstruction, pulmonary venous thrombosis, respiratory distress, flail chest, lung contusion, bronchopneumonia, and severe vascular injury in 1 case each. Table IV also indicates that there was a single case where three surgeons independently indicated that the death was "definitely preventable." The cause of death in this last instance was an iatrogenic event related to anesthesia administration.

Tables IV and V also indicate substantial agreement with regard to cases that three or four surgeons independently judged to be unsalvageable. There were 105 trauma cases in which three or more surgeons rated the case as unsalvageable when it occurred and where at least three

surgeons also rated it as unsalvageable if the trauma were to be sustained today. The causes of death in these 105 cases were general intracranial injury in 58 cases, cerebral hemorrhage/edema in 20 cases, brainstem injury in 10 cases, hemorrhage/coagulopathy in 7 cases, multiple organ trauma in 6 cases, and severe burns and hemopneumothorax in 2 cases each.

Agreement Whether Technology/Training/First Responder Would Make a Difference

In 7 of the 210 trauma cases reviewed, there was unanimous agreement among the surgeons that deployment of medical technologies might make a difference in whether that particular trauma would be salvageable today. In another 18 cases, 3 of the 4 doctors agreed that now-available technologies might make a lifesaving difference for a particular trauma. The kappa statistic for the level of agreement on this question was 0.158. The level of agreement as to whether training would make a lifesaving difference was slightly lower: in only 2 trauma cases did all four surgeons agree training would have a lifesaving difference; in another 20 trauma cases three surgeons agreed training would have a difference. The kappa statistic for level of agreement on this issue was 0.138. While the surgeons did not always agree on the specific technologies that would make a difference, the most prevalent responses to the specific technologies and training that would prove useful are seen in Tables VII and VIII.

In response to the question whether the actions of a "first responder" might make a lifesaving difference with respect to the traumas reviewed, there was considerable agreement that such actions would not have made a difference. Three of the surgeons thought the actions of a first responder might make a difference in an average of only 1.5% of the 210 cases. However, the fourth surgeon felt that that a first responder might make a difference in almost one-fourth of the cases. This fourth surgeon advocated the following activities by the first responder in various trauma cases: early field intubation, use of tourniquet and pressure dressing, and early use of antibiotics. It is noted that no documentation was available as to the actions, if any, that had actually been taken by first responders in these trauma cases.

DISCUSSION

The present investigation sought to assess the likelihood of combat deaths in future military operations being reduced via certain medical practices, and, if some deaths might be prevented, to illuminate the specific medical technologies and/or training that would yield such lifesaving

differences. The clinical records reviewed were a randomly selected representative sample of the combat wounds that ended in death after reaching a medical treatment facility. All four surgeons who reviewed the 210 clinical records of combat traumas ending in death at treatment facilities in the Vietnam conflict believed that, if the traumas were incurred today, some deaths would be "definitely preventable" and others would be "possibly preventable." There was unanimous agreement that 8% of the deaths would be possibly preventable if incurred today, and near-unanimity that another 17% of the deaths would be possibly preventable. It is noted that often in "preventability of death" studies, the surgeons reviewing the clinical records form a working panel where attempts are made by individual surgeons to persuade fellow panelists of the "correctness" of his/her judgment. A major strength of this study is that, because the surgeons did not communicate, where there was agreement, that agreement was independently achieved. Further, as measured by the kappa statistic, there was fair agreement among the surgeons as to whether the reviewed deaths were preventable/unsalvageable.

A major focus of this study was on traumas judged to be unsalvageable when they occurred but where the deaths were deemed preventable if the same traumas were incurred today. That there was near-unanimity that a life could not be salvaged 30 years ago, and then near-unanimity that the same death might be preventable today, suggests that for these 26 trauma cases there have been advances in medical practices that would potentially have a lifesaving impact. The fatal wounds most commonly viewed as preventable today were traumas where the cause of death was hemorrhage, severe burns, pulmonary edema, and sepsis.

While individually all four surgeons thought many traumas would benefit from the deployment of specific technologies and/or training, there was not substantial agreement as to the specific trauma cases that would benefit. Nevertheless, at least 3 of the 4 surgeons thought that technologies and training would have a lifesaving impact in 11% and 10% of the trauma cases respectively. The medical technologies/equipment most often mentioned to have a potentially lifesaving effect were ventilators/respirators, CT scanners, ultrasound, and antibiotics. The types of training most often mentioned to have a potentially lifesaving impact were damage control, ventilator management, liver packing, respiratory distress management, and burn management.

The surgeons largely disagreed with the notion that the actions of a first responder might make a difference in the salvageability of the combat deaths they reviewed. Where actions by a

corpsman or medic were thought to possibly make a difference, those actions included field intubation, hemorrhage control, and administration of antibiotics in the field.

The judgments of the surgeons reviewing the records of this study indicate that reductions in the incidence of battlefield deaths through improved medical technologies and training are likely possible. A number of the comments of the surgeons highlighted the fact that combat casualty care actually occurs along a continuum that potentially involves fellow combatants, corpsmen, personnel at battalion aid stations, medevac personnel, and the doctors and nurses at the hospitals where the wounded eventually arrive. While the focus of the present investigation was the care received after arrival at hospitals, it is possible that battlefield deaths might be reduced through technologies and/or training at each link of the casualty care continuum.

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14. ABSTRACT (maximum 200 words)

Clinical records were obtained for 210 combat trauma cases that ended in death subsequent to reaching a medical treatment facility. Four surgeons were recruited to review these records and assess the preventability of death if the traumas were sustained today, and to provide judgments as to now-available medical technologies and/or training that might make a lifesaving difference. In 8% of the cases, the four surgeons independently agreed that the deaths would be possibly preventable if the same traumas were incurred today; in an additional 17% of the cases, three of the four surgeons judged the deaths to be possibly preventable today. The fatal wounds most often viewed as salvageable today were hemorrhage, severe burns, pulmonary edema, and sepsis. The medical technologies most often mentioned to have a potentially lifesaving effect were ventilators/respirators, CT scanners, ultrasound, and antibiotics. The types of training most often mentioned to have a potentially lifesaving impact were damage control, ventilator management, liver packing, respiratory distress management, and burn management.

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